Optimization of the Open-Hole Method for Assessing Pocket Gopher, *Thomomys* spp., Activity

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The open-hole method is widely used for monitoring activity of pocket gophers (*Thomomys* spp.) in western forests. We examined the open-hole method in a field study to optimize the number of holes to open and the number of burrow systems to observe. Sensitivity of assessing burrow system activity was minimally affected if two of three opened holes in each system were monitored, whereas there was a 20% decrease in sensitivity if only one hole was monitored. For general activity assessment purposes, a random sample of 30 burrow systems with two burrows opened per system appears to be an optimum mix to achieve sensitivity in activity estimates, without producing excessive labor in the field.

Key Words: Mazama Pocket Gophers, *Thomomys mazama*, burrow system, activity index, Oregon.

Because pocket gophers (*Thomomys* spp.) are fossorial, their activity is inferred by observing their sign. Monitoring pocket gopher activity is especially essential for forest research and management purposes, as pocket gophers are a major hindrance to natural and artificial reforestation in the western United States, probably injuring and destroying more conifer seedlings than all other animals combined (Barnes 1973; Crouch 1986; Borrecco and Black 1990). Activity levels of pocket gophers are often assessed as a means to predict the potential for population growth or invasion into reforestation units, and to determine whether damage reduction measures may be necessary or have been effective.

The open-hole method (Richens 1967; Barnes et al. 1970) provides an effective index of Pocket Gopher activity (Engeman et al. 1993). Briefly, the method involves locating a pocket gopher burrow system and opening one or more holes, then returning 48 hours later to determine whether the holes remain open or have been closed by the resident animal (Richens 1967; Barnes et al. 1970). Usually, two or three openings are created in each suspected active pocket gopher system. Pocket gophers maintain closed burrow systems and will readily plug openings in their burrows. They also lead solitary lives, so each identified system likely has one resident. Closure of any one of the burrow openings is cause for the system to be considered active.

In the present study we examined further optimization of the open-hole method. We assessed the optimal number of open holes required per burrow system to provide a reliable indicator of activity (Engeman et al. 1993). We also documented the precision of the estimated proportion of pocket gopher systems that are active within a given area when different numbers of burrow systems are sampled.

Methods

The study was conducted in southern Oregon on Ponderosa Pine (*Pinus ponderosa*) reforestation units in the Rogue River National Forest (42° 08' N, 122° 18' W) during the early fall of 1996. Six 2.8 ha sites (140 × 200 m) with similar age stands were selected for the study. All sites were populated with Mazama Pocket Gophers (*T. mazama*), which were the primary causal factor for seedling survival failure each of the two or three times the sites were planted within the past ten years. Each site was divided into a grid of 20 × 20 m cells to aid in the systematic examination of all pocket gopher burrow systems. Each cell was then examined and flags placed wherever there were signs of pocket gopher activity (i.e., mounds). Subsequently, we created three open-holes between the surface and the burrow system in the vicinity of each flag. After 48 hours, each opening was examined for pocket gopher activity as indicated by closure (plugged by a gopher). A burrow system was considered active if any of the three openings was observed to be closed.

The data on the number of openings plugged at each burrow system allowed us to conduct a probabilistic assessment of whether a burrow system would have been found active if only one or two of the original openings were created in the burrow system, instead of three. The assumption required for these calculations is that the outcome of plugged or unplugged for each hole in each system would have been the same whether one, two, or three of the original holes had been opened. Inferences that

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TABLE 1. Number (percent) of burrows openings at each study site with 0, 1, 2, or 3 closures after 48 hours.

| Site | Number of burrow openings closed | | | | Total |
	0	1	2	3	
1	10 (12.0)	7 (8.4)	32 (38.6)	34 (41.0)	83
2	3 (2.6)	14 (12.1)	29 (25.0)	70 (60.3)	116
3	2 (2.7)	6 (8.2)	29 (39.7)	36 (49.3)	73
4	4 (7.8)	7 (13.7)	10 (19.6)	30 (58.8)	51
5	15 (11.5)	21 (16.2)	39 (30.0)	55 (42.3)	130
6	13 (10.1)	16 (12.4)	44 (34.1)	56 (43.4)	129
Total	47 (8.1)	71 (12.2)	183 (31.4)	281 (48.3)	582

follow directly from this assumption include: (1) systems where all three holes were found to be closed also would have been found active if only one or two of the original three holes had been opened; (2) systems where two of the three holes were found to be closed, also would have been found active if only two of the three original holes had been opened, and two-thirds of these systems would have been found active if only one of the three original holes been opened; (3) two-thirds of those systems where only one of the three holes was closed would still have been found active if two of the original three holes had been opened, and one-third of those same systems would have been found active had only one of the original holes been opened.

We then estimated the number of burrow systems that would have been found active had we initially opened one or two of the three original holes in each system. In the following equations n_1 = number of burrow systems with one of three openings closed, n_2 = number of burrow systems with two of three openings closed, and n_3 = number of burrow systems with all three openings closed.

Number of holes opened	Number of burrow systems that would have been found active (A)
3	$A = n_3 + n_2 + n_1$
2	$A = n_3 + n_2 + n_1(0.667)$
1	$A = n_3 + n_2(0.667) + n_1(0.333)$

Besides examining the number of holes plugged within each burrow system, we also assessed precision and confidence intervals of our estimates of population activity if samples of 10, 20, 30 or 40 burrow systems had been taken at each site, rather than using all burrow systems on each of the six 2.8 ha sites.

Results

Anywhere from zero to three of the openings in each burrow system were closed by the resident pocket gopher (Table 1), but most often, all three openings were closed. Using the equations given in the Methods section, we used these data to generate

TABLE 2. Number of burrow systems at each of six sites that would have been found active if one, two or all of the original three holes had been opened. The number of active burrow systems estimated for one and two holes is followed by the percent of systems active relative to the three-hole method.

| | Number of burrow openings | | | | |
Site #	3	2		1	
1	73	71	97.3%	58	79.5%
2	113	108	95.6%	94	83.2%
3	71	69	97.2%	57	80.3%
4	47	45	95.7%	39	83.0%
5	115	108	93.9%	88	76.5%
6	116	111	95.7%	91	78.4%
Total	535	511	95.5%	427	79.8%

TABLE 3. Percentage of active burrow systems at the six study sites and standard deviations associated with sample sizes of 10, 20, 30 and 40 burrow systems. The standard deviations for hypothetical activity levels ranging from 10 to 90% are also presented for these sample sizes.

| Site | % Active | Standard deviation | | | |
		n=10	n=20	n=30	n=40
1	88.0%	10.3	7.3	5.9	5.1
2	97.4%	5.0	3.6	2.9	2.5
3	97.3%	5.1	3.6	3.0	2.6
4	92.2%	8.5	6.0	4.9	4.2
5	88.5%	10.1	7.1	5.8	5.0
6	89.9%	9.5	6.7	5.5	4.8
Hypothetical	10.0%	9.5	6.7	5.5	4.7
	20.0%	12.6	8.9	7.3	6.3
	30.0%	14.5	10.2	8.4	7.2
	40.0%	15.5	11.0	8.9	7.7
	50.0%	15.8	11.2	9.1	7.9
	60.0%	15.5	11.0	8.9	7.7
	70.0%	14.5	10.2	8.4	7.2
	80.0%	12.6	8.9	7.3	6.3
	90.0%	9.5	6.7	5.5	4.7

activity assessments as if only one or two of the original three openings in the burrow systems had been made. The results, summarized across sites, are given in Table 2. In 95.5% of the cases, two openings would have provided the same assessment of activity as using three openings, whereas one opening would have provided the same activity assessment in only 79.8% of the burrow systems. We calculated the standard deviations for burrow system activity estimates for each of the six sites, as well as for hypothetical activity levels ranging from 10 to 90%, for sample sizes of 10, 20, 30 or 40 burrow systems (Table 3). While sampling more burrow systems results in a smaller standard deviation, the size of the standard deviation also is influenced by the proportion of active systems, with highest values occurring when the proportion active is at 50% (Table 3).

Discussion

Sensitivity in assessing burrow system activity was minimally affected if two of the original holes were opened (Table 2). An average of 96% of the systems found active using three holes also would have been found active had only two of those holes been used. Reducing the number of holes opened to two rather than three may be pertinent, considering that a 33% decrease in the labor applied to each system was estimated to produce only a 4% decline in sensitivity, which may be particularly important in areas where burrows are difficult to locate. Sensitivity for measuring activity, however, was estimated to drop by 20% if only one of the original three holes had been opened. Probably, this would present an unacceptable potential to underestimate activity for most research or management purposes.

The trends displayed in Table 3 are not surprising, but the values should assist decision making on the number of burrow systems that need to be sampled within a site. The greatest standard deviation (least precision) occurs when the proportion of active and inactive burrow systems nears 50%. The standard deviation decreases symmetrically as the proportion decreases or increases away from this midpoint (e.g., the precision for a proportion of 10% is the same as that for 90%). The standard deviation also is inversely proportional to the square root of the sample size. Thus, incremental increases in sample size produce diminishing benefits in precision. Activity levels such as occurred at our study sites (e.g., > 80%) result in estimates with less variation than for mid-range activities. Within the observed ranges, a random sample of 30 burrow systems, with two or three holes opened per system, is probably adequate for most applications of activity assessments. Larger sample sizes, however, may be required to obtain acceptable precision on sites with activity levels in the mid-ranges.

This paper describes relationships based on data collected from sites containing pocket gophers in cleared forest habitats, but the results may not be as applicable for other circumstances. For example, Matschke et al. (1994) determined that the open-hole method in an agricultural setting provided assessments of activity for the Townsend's Pocket Gopher (*T. townsendii*) that were biased high. Unlike the forest pocket gophers for which the open-hole activity assessment method is commonly used (*T. talpoides* and *T. mazama*), the Townsend's Pocket Gophers were not solitary in their occupancy of burrow systems (Matschke et al. 1994). Thus, Matschke et al. (1994) observed that a population reduced by strychnine bait produced nearly the same activity levels as prior to application of the toxicant (91.6% versus 97.9%). This result reinforces the principle that parameters need to be verified for untested situations prior to basing inferences on the method.

Besides testing the method in new situations, further optimization of the open-hole method is possible. As an example, the lag time between opening holes in a burrow system and rechecking them for closure is typically 24 or 48 hours, but this time period, to our knowledge, has not been optimized. Ideally the lag time should be adequate for the resident animal to plug at least one hole, but that lag time should be insufficient to allow an appreciable probability for re-invasion into unoccupied burrow systems (which can occur rapidly).

It is a common problem in wildlife biology that direct population monitoring methods are logistically complex or costly. This is especially true for fossorial animals. Here we have refined the application of an easy-to-apply and inexpensive method for monitoring pocket gophers. Improved understanding of the application parameters for this indirect observation method using sign of animal activity allows accurate inferences about population levels with minimal effort and cost.

Acknowledgments

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